The Waterworks of Europe.

II. EUROPEAN CONTINENT.

Paris, France; Florence, Italy; Moscow, Russia; Vienna, Austria; Munich and Frankfort-on-the-Main, Germany; Geneva and Zurich, Switzerland.

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THE WATERWORKS OF EUROPE.

II. EUROPEAN CONTINENT.

The question of pure water has formed for years one of the most essential problems to be dealt with by the Administration of every great city of the European Continent. This question has become a highly scientific one, and great progress has been made during recent years in the water supply of large cities. With the rapidly increasing population and the growing industrial development of large towns the quantity of water required increases from year to year, and even cities with model waterworks are often, after a relatively short time, compelled to increase again and again the capacity of their waterworks and sewerage systems. In many instances the greatest technical difficulties have to be overcome, and the sums to be expended are enormous. That city is fortunate where the natural conditions are favorable to the establishment of a healthy and sufficient water supply.

Before going into details in reference to the waterworks of leading Continental cities, it will doubtless be of interest and value to review the following regulations issued by the German Government, which indicate the different methods recommended for the guidance of water companies in Germany. At the same time it may be stated that the following reports are based upon information gathered by the Philadelphia Commercial Museum from official sources, and in many instances the Museum is indebted for the information to the courtesy of the Chief Engineers and Directors of the several foreign waterworks.

The German regulations read as follows :

1. In judging the quality of a filtered surface water the following points should be specially observed : (a) The operation of the filter is to be regarded as satisfactory when the filtrate contains the smallest possible number of bacteria, not exceeding the number which practical experience has shown to be attainable with good filtration at the works in question. In those cases where there are no previous records showing the possibilities of the works and the influence of the local conditions, especially the character of the raw water, and until such information is obtained it is to be taken as a rule that a satisfactory filtration will never yield an effluent with more than about 100 bacteria per cubic centimeter. (b) The filtrate must be as clear as possible, and in regard to color, taste, temperature and chemical composition must be no worse than the raw water.

2. To allow of a complete and constant control of the bacterial efficiency of filtration the filtrate from each single filter must be examined daily. Any sudden increase in the number of bacteria should cause a suspicion of some unusual disturbance in the filter, and should make the Superintendent more attentive to the possible causes of it.

3. Filters must be so constructed that samples of the effluent from any of them can be taken at any desired time for bacteriological examination.

4. In order to secure uniformity of method the following is recommended as the standard method for bacterial examination: The nutrient medium consists of 10 per cent. meat extract gelatine with peptone, 10 cubic centimeters of which is used for each experiment. Two samples of the water under examination are to be taken—one of 1 cubic centimeter and one of ½ cubic centimeter. The gelatine is melted at a temperature of from 30° Cent. to 35° Cent. and mixed with the water as thoroughly as possible in the test-tube by tipping backwards and forwards, and is then poured upon a sterile glass plate. The plates are put under a bell-jar which stands upon a piece of blotting paper saturated with water, and in a room in which the temperature is about 20° Cent. The resulting colonies are counted after forty-eight hours, and with the aid of a lens. If the temperature of the room in which the plates are kept is lower than the above, the development of the colonies is slower, and the counting must be correspondingly postponed; if the number of colonies in 1 cubic centimeter of the water is greater than about 100, the counting must be done with the help of the Wolffhuegel apparatus.

5. The person entrusted with the carrying out of the bacterial examinations must present a certificate that he possesses the necessary qualifications, and, wherever possible, he shall be a regular employé of the waterworks.

6. When the effluent from a filter does not correspond with the hygienic requirements, it must not be used, unless the cause of the unsatisfactory working has already been removed during the period covered by the bacterial examinations. In case a filter yields, for more than a very short time, a poor effluent, it is not to be used until the cause of the trouble is found and corrected. It is, however, recognized from past experience that sometimes unavoidable conditions (high water, etc.) render it impossible, from an engineering standpoint, to secure an effluent of the standard quality. In such cases it will be necessary to use a poorer quality of water; but, at the same time, if such conditions arise as outbreaks of epidemics, suitable notice should be given of the condition of the water.

7. Every single filter must be so built that, when an inferior effluent results which does not conform to the standard, it can be disconnected from the pure water pipes, and the filtrate allowed to run to waste. This wasting should, as a rule, take place, so far as the arrangement of the work will permit, (1) immediately after scraping a filter, and (2) after replacing the sand to the original depth. The Superintendent must himself judge, from previous experience acquired by continual bacterial examinations, whether it is necessary to waste the water after these operations, and if so, how long a time will probably elapse before the water reaches the standard purity.

8. The best sand filtration requires a liberal area of filter surface, allowing plenty of reserve, to secure, under all local conditions, a moderate rate of filtration adapted to the character of the raw water.

9. Every single filter shall be independently regulated, and the rate of filtration, loss of head and character of the effluent shall be known; although each filter shall, by itself, be capable of being completely emptied, and, after

scraping, of having filtered water introduced from below until the sand is filled to the surface.

10. The velocity of filtration in each single filter shall be capable of being arranged to give the most favorable results, and shall be as regular as possible, quite free from sudden changes or interruptions. On this account reservoirs must be provided large enough to balance the hourly filtration in the consumption of water.

11. The filters shall be so arranged that their working shall not be influenced by the fluctuating level of the water in the filtered water reservoir or pump-well.

12. The loss of head shall not be allowed to become so great as to cause a breaking through of the upper layer on the surface of the filter. The limit to which the loss of head can be allowed to go without damage is to be determined for each works by bacterial examinations.

13. The filters shall be constructed throughout in such a way as to insure the equal action of every part of their area.

14. The sides and bottoms of filters must be made water-tight, and special pains must be taken to avoid the danger of passages or loose places through which the unfiltered water on the filter might find its way through the filtered water channels. To this end special pains should be taken to make and keep the ventilators for the filtered water channels absolutely tight.

15. The thickness of the sand layer shall be so great that under no circumstances shall it be reduced by scraping to less than 30 centimeters (12 inches), and it is desirable, so far as local conditions allow, to increase this minimum limit. Special attention must be given to the upper layer of sand, which must be arranged and continually kept in the condition most favorable for filtration. For this reason it is desirable that, after a filter has been reduced in thickness by scraping, and is about to be refilled, the sand below the surface, as far as it is discolored, should be removed before bringing on the new sand.

16. Every city in the German Empire using sand-filtered water is required to make a quarterly report of its working results, especially of the bacterial character of the water before and after filtration, to the Imperial Board of Health.

17. The question as to the establishment of a permanent inspection of public waterworks, and if so, under what conditions, will be best decided after such quarterly reports have been furnished over some period of time.

Paris, France.

Paris, the capital of the French Republic, is not only the commercial and financial, but also the industrial, center of the French Republic. According to a census taken in 1896, its population was 2,511,955. It is the largest city of the European Continent, and the second largest city of Europe, being outranked only by London. Paris, at the same time, is more densely populated than any other city of Europe, there being as an average 290 persons to each hectare (2.471 acres). The average lifetime is twenty-eight years, as against forty in the whole of France.

The city actually has six different water conduits, of which the four

principal are: Canal de l'Ourcq, and the aqueducts de la Dhuis, de l'Avre and de la Vanne; furthermore, there are two artesian wells in Grenelle and Passy of more than 500 meters (or about 1640 feet) deep, twenty pumping stations with forty-one steam engines and twenty-two hydraulic motors of a total capacity of 4000 horse-power, twenty large reservoirs erected on the highest points of the city and built of stone of a capacity of over 500,000 cubic meters, or about 17,500,000 cubic feet of water. The length of the conduits is 2067 kilometers, or 1284 miles, with about 17,000 distributing points on the public roads and institutions, and 52,000 water meters. The daily consumption of water within the city amounts to about 19,600,000 cubic feet.

In regard to the water supply in Paris, the circumstances were formerly very similar to those now prevailing in London. The administration of the supply was in the hands of a powerful commercial company, La Compagnie Générale des Eaux, which drew water from the Seine and Marne, and lifted it with pumps into reservoirs, from which it was supplied to the ground floor of the houses, the pressure not being sufficient to reach the upper stories.

When the communes outside the inner walls (barrières) were included in the metropolis, the river Seine was considered less suitable as a source of water supply for drinking purposes, owing to the multiplication of works, the increase of the population along the banks and the consequent increase of pollution. It was therefore resolved to buy up the Compagnie Générale des Eaux, and a contract was entered into on July 11, 1860, by virtue of which the city of Paris agreed to pay to the company fifty annuities of $232,000 each, making a total of $11,600,000 for the lands, machinery, mains, reservoirs and plants of every kind, which the company possessed in the department of the Seine, and in consideration of the forfeiture of their contracts with the communes just included in the city of Paris. The company no longer had anything to do with the business of distribution, but they continued to collect the water charges from the consumers, and for this service they received a percentage of the receipts collected by them.

The system resulting from the contract of 1860, which transferred the ownership and management to the municipality of Paris, has been much to the advantage of the city, and no one in Paris would recommend reversion to a system under which the water supply would be administered by a private company.

Since 1880 the water charges have been considerably lowered. As soon as the city of Paris became possessed of her own water supply she set to work at once to bring in a supply of pure water. The first important source was that of the Dhuis. The total length of the aqueduct was about 82 miles, and the water comes from Verdon and Surmelin Valleys, whence it is taken to the reservoir at Menilmontant by gravitation at the natural fall of 0.10 meters per 1000 meters. The average volume thus brought into the reservoir, which is capable of holding 3,325,000 cubic feet, each day is 700,000 cubic feet. The cost, including the purchase of the springs, compensation to millowners and others, and the building of the aqueducts, amounted to $3,600,000.

Additional water was brought from the Vanne in 1870 and 1894 by an

aqueduct of 107 miles, 10 being on arches. These works presented difficulties, and cost $7,800,000. The water also comes by gravitation into the Montrouge reservoirs, which cost about $2,000,000. A small secondary supply was derived from the Cocheysies springs in 1881-88. It cost $636,000, and gave a regular average output of 4,200,000 cubic feet per day. The Vigne and the Avre, from which water was taken in 1892-94, necessitated an outlay of about $7,000,000 for a quantity of 4,025,000 cubic feet, brought by an aqueduct 63½ miles long into the Montretout reservoirs, not yet completed, but working since 1896.

In the year 1896 the water expenses were $1,021,200 and the receipts amounted to $3,400,000, whilst in 1897 the expenses were $1,037,000 and the receipts the same as in the previous year. There is an organization in Paris similar to the Thames Conservency, the department of sources, sanitation and sewers, whose special duty is to prevent pollution.

The spring water is not mixed with the Seine water, as there are special reservoirs for each, although there are not special distribution pipes in every case. Spring water is supplied as long as there is spring water to supply; and the Seine water, which is not always filtered, is only supplied in cases of absolute necessity in times of extreme drought. When the Seine water is being used, of which public notice is always given in the newspapers and by means of placards, the bacteriological condition of the pipes becomes very bad indeed, and the object which the municipality have in view is to dispense with even occasional use of the Seine water and to use spring water for all purposes.

It may be noted that apparently French bacteriological observations in the case of filtered as compared with unfiltered water do not accord with those obtained in Berlin, and, in fact, throughout Germany generally.

Seine water is used for watering the streets and in the parks and gardens, and for this purpose there is a double canalization, with no connection between the two sets of mains.

The capital expended by the municipality in taking over the water company's works and bringing spring water from a distance was raised by the issue to the public of bonds bearing different rates of interest, redeemable by drawings, and secured on the octroi duties and general taxes of Paris in such a way that, if the water rates did not meet the total expenditure, including interest and sinking fund, the balance was paid out of the Paris general rate, which came, to some extent, out of the pockets of the inhabitants of the city.

The Municipal Council of Paris has recently appointed a Commission to examine the projects which have been presented for bringing fresh supplies of water to the city, and when the final report of this Commission shall have been approved, the Council will vote the necessary credits for carrying out a vast system of water distribution. At present the average daily consumption of water within the city is, as already stated, 9,600,000 cubic feet, representing 220 liters, or 52.816 gallons per head of population.

With the exception of Rome, this is the largest consumption of any European capital, and even among the leading cities of the world Paris occupies a fairly high rank in the abundance of its artificial water supply.

Notwithstanding the relative completeness of its system of water distribution Paris has often found itself short of water during times of long drought, when it has been necessary to supplement the supply from the filtering beds and from the sources of the Avre, the Vanne and the Dhuis with water drawn direct from the Seine. Not only is it absolutely indispensable to look to further sources in order to provide against such contingencies, but it is also evident that the city must be thoroughly equipped with an abundant water distribution by the time of the Exposition of 1900 and, moreover, the constant increase in the population is a factor that enters seriously into the calculations of engineers. At the present rate of progress it is estimated that in 1930 the population will be 3,300,000; but in view of the fact that the boundaries cannot extend so long as the present fortifications exist, it is not expected that this figure will ever be exceeded. This is the basis taken by engineers in calculating the importance of the system of water distribution to be carried out during the next twenty years.

Of the 9,600,000 cubic feet of water distributed every day in Paris, there are only 8,855,000 cubic feet available for domestic purposes; that is to say, 7,105,000 feet of spring water and 1,750,000 feet of filtered water. This quantity would be quite sufficient at all seasons of the year if it were not for the considerable waste, for which it is not easy to provide a remedy. The Paris engineers do not think that it is possible to devise a means of enforced economy in water consumption, and the only alternative, therefore, is to augment the supply. It is believed that something may be done in this direction by reducing the loss in the main conduits to a minimum. Seeing that the length of the Vanne conduit is 107 miles, the Dhuis 81 miles and the Avre 63 miles, it is evident that a good deal of water must be lost during conveyance over such long distances. According to recent estimates, the loss from leakages and defects in the conduits amounts to about 25 per cent. in the United States and 30 per cent. in England, and it is certain that in France the loss is no less. It is therefore proposed to increase the grant for the inspection of the conduits, in order that any defects may be promptly made good. By the time the population reaches its maximum—that is to say, in 1930—it will be necessary to augment the supply of pure water by at least 2,450,000 cubic feet a day. The sources of the Loing and the Lunain will provide from 1,400,000, to 1,750,000 feet, and the remainder may be obtained from the filtering basins or by utilizing certain other river sources within a convenient radius of the city. The Municipal Council, however, does not propose to confine itself to this limit, but to give an ample margin by providing a daily supply of 14,000,000 cubic feet of pure water, which will represent 120 liters or 31.71 gallons per head of population. This would be more than sufficient for the domestic needs of the people.

Several projects have already been presented to the Municipal Council for obtaining the additional 5,600,000 cubic feet necessary to make up this total and they may be grouped under three heads; that is to say, the utilization of new springs, the creation of filtering beds, and the bringing of water from the Swiss lakes. This last-named project has been strongly advocated by certain engineers, who point out the alleged enormous advantages that

would accrue from the conveyance of practically unlimited supplies of water from the Lake of Geneva. It has been estimated that 17,000,000 cubic feet a day would thus be available for Paris. The difficulties of the scheme, however, are so considerable that it has been rejected by all the commissions which have reported upon it. Even supposing that the Swiss Government would consent to such a mass of water being taken from the Lake of Geneva, the cost of constructing an aqueduct of 500 kilometers, or about 311 miles, would be no less than $120,000,000, and it would be necessary to rearrange the entire system of water distribution in the city. Besides this question of cost, it is asked whether any reservoir and conduit could be made strong enough to resist the pressure of such a mass. Since the Bouzey catastrophe, French engineers have begun to exercise more than ordinary caution in dealing with the enormous pressures in the reservoirs. Again, is it advisable to procure the whole water supply from a single source and thus run the risk of supplies being cut off through an accident to the conduit? A still more powerful argument against the scheme is the poor quality of water in the Lake of Geneva. Being formed largely of melted snow, the water contains very little salts and mineral constituents, and in any event is not so pure as spring water. This great project having been definitely set aside, the municipal engineers are discussing the various other means of augmenting the water supply. At first it was proposed to make the best of the existing supplies by building an immense reservoir to receive the surplus during the greater part of the year, when the quantity available exceeds the consumption, and thus have an ample reserve during the months of comparative drought. This, however, would have necessitated a reservoir with a capacity of 157,500,000 cubic feet, and it would cost three times more than the construction, say, of the Dhuis aqueduct. Moreover, the water would be liable to contamination and might be a source of danger to the health of the city. It is thus preferable and more economical to bring the water direct from new springs. In two years' time the completion of the works for utilizing the sources of the Loing and the Lunain will suffice for the normal needs by increasing the minimum total of spring water from 7,000,000 cubic feet to about 8,750,000 cubic feet, and with this additional pressure it will be possible to send the water at all times to the highest points in Paris.

The Exposition of 1900, however, has rendered it necessary to augment the existing supplies of spring water with 2,275,000 cubic feet a day of filtered water. As the result of a competition organized quite recently, the Municipal Council has come to the conclusion that the only way of satisfactorily dealing with the river water is by filtering it through beds of sand. The capacity of the Saint-Maur sand basins is at present 700,000 cubic feet, and this is to be increased before long to 1,050,000 or 1,400,000 cubic feet. It is found inadvisable to take more than this quantity from the river Marne, and the new basins are to be established near the Seine at Ivry. Eventually the filtering basins will have a capacity of 3,500,000 cubic feet, which will represent a quarter of the entire supply of water estimated to be available in 1930. To complete this distribution of 14,000,000 cubic feet of pure water it will be necessary, as we have said, to utilize fresh sources capable of furnishing

about 5,600,000 cubic feet a day. The proposal to bring water from the springs of the Aube, the Yonne and the Seine, which are capable of furnishing all that is necessary, will only be recommended by the engineers as a last resource, owing to the strong local opposition that has to be met with, and the heavy expense that would probably have to be incurred in indemnities and the like. They have, therefore, revived an old project for utilizing the water which exists in the vast subterranean collieries near Orleans. For a distance of 41 kilometers, or about 25½ miles, before entering Orleans, the river Loire gradually decreases in volume by the filtration of the water through the gravel and loose calcareous beds of the valley, and the water rises again 9 kilometers below Orleans to swell the Loire and the Loiret, where the volume is about the same as at the point where the filtration begins. The town of Orleans obtains its water from this natural reservoir, and it is estimated that Paris might procure no less than 15,120,000 cubic feet a day; so that not only would the city be abundantly supplied with spring water, but there would be enough for distribution in the suburbs. As this amount represents a fifth of the volume of the Loire at its lowest water level, it is evident that such a heavy drain would cause serious inconvenience during a period of drought, especially in view of the agitation now being carried on to render the Loire navigable for vessels of light draught; and in order to overcome this drawback it would be necessary to construct dams across some of the upper valleys of the Allier and the Loire to form reservoirs with a total capacity of 1,750,000,000 cubic feet, or sufficient to feed the river during a month of drought. The Commission, which has already examined this project, estimates that the cost of these works will not exceed $24,000,000. According to analyses of water taken from the calcareous beds through which it has filtered, the quality is excellent; but upon this point, as upon many others, the new Commission lately appointed to examine all the various schemes will make further investigation before recommending the adoption or otherwise of this important project. In the meantime, it is proposed to build an additional reservoir in Paris so as to obviate the necessity of using the Seine water for domestic purposes during the hot months of the year, when the heavily increased consumption coincides with the fall in the yield from the various springs, and it is pointed out that such a reservoir would enable the Council to spread the works over a longer period than would otherwise be possible.

The program of the Paris Municipal Council to be carried out before 1900 is as follows: The construction of aqueducts from the Loing and the Lunain, which has already been started upon, and is to be completed in two years; the construction of filtering basins, bringing up the total capacity to 2,275,000 cubic feet of filtered water a day; the provision of a reserve of river water equal to 4,550,000 cubic feet a day; the preparation of plants for bringing a fresh supply of 5,600,000 cubic feet of spring water to Paris; and the carrying out of the works of distribution in the city. It is estimated that this program will entail the expenditure of $34,500,000. Of this sum, $5,300,000 will be spent upon the Loing and the Lunain works, and $5,840,000 upon the enlargement of the filtering basins at Saint-Maur and the creation

of new basins at Ivry. A sum of $505,000 will also be devoted to strengthening the Vanne and Dhuis aqueducts and the acquirement of new springs. After 1900 the works will be carried out in two periods, when it is estimated that $15,600,000 will be spent upon new conduits and reservoirs, $500,000 for the completion of the filtering basins and $3,300,000 for improvements to existing works. As regards the elevating and distributing installations for the water of the Seine a sum of $3,060,000 will be spent upon pumping machinery, siphons, reservoirs and general improvements before 1900, and close upon $5,000,000 will be devoted to completing the system after that period.

Florence, Italy.

Florence (Italian "Firenze") is situated at the head of navigation on the Arno, at the foot of the Apennines, on the railway lines of Bologna-Rome and Florence-Pisa. The river Arno divides the city into two sections. Florence is one of the finest and most interesting cities in Italy. During the "season" it offers a most interesting picture of high life and entertains within its walls a large number of royal and princely personages. The population is about 200,000. Florence is more an art than an industrial city, although the manufacture of silks, straw hats, porcelain, glassware, etc., is carried on.

The temperature of Florence is subject to considerable and sudden variations even during the daytime. It averages annually 58 degrees 1 minute, with a maximum of 103 degrees 1 minute and a minimum of 12 degrees 2 minutes.

Fog is not unfrequent in winter, but it is rarely very dense. It is reckoned that there are in Florence 107 rainy days during the year, the average annual rainfall being calculated at 35.618 inches. For a long period of years the maximum number of successive rainy days was twenty-three. Snow is rather unusual; hailstorms, generally accompanied by rain, may average six per annum. There are about eighty days in the year of rather strong winds, predominating in winter from northeast and southwest and in summer from west and northwest.

The Arno is provided with two water gates—the upper one near the Porta San Nicolo furnishes hydraulic power for lifting the drinking water from the subfluvial galleries to the reservoirs, the other provides through a canal the motive power for the Government tobacco mills at the Cascine. The Arno is navigable for small boats from the landing stage at the Pignone below the town to the sea, and is especially used for the conveyance of timber from the woods of Vallambrosa which are floated down the river.

The length and average breadth of the Arno and of the torrents Mugnone, Terzolle and Affrico within the town are as follows:

	Length. Yards.	Breadth. Yards.
Arno	9,077	142
Mugnone	8,918	13½
Terzolle	2,625	17
Affrico	4,808½	4

There are within the commune no marsh lands or stagnant waters.

The sewerage inside the town consists of a net of sewers, of an ovoidal section allowing circulation, converging into two mains leading into the Arno.

The following table shows the length and cost of the whole system :

	Length in Yards.	Cost.	Total.
To March, 1883.			
Mains	11,483	$ 952,000	
Secondary mains	81,595	2,338,330	
Sub-mains	26,221	239,770	
Sub-mains (smaller) . . .	39,554	217,015	$3,747,115
From March, 1883, to January, 1887.			
Sewers of a reduced, but allowing personal, circulation inside the city walls .	3,250	$59,520	
Sewers of a reduced, but allowing personal, circulation outside the city walls	3,495	31,550	91,070
From 1887 to 1891 (June).			
Sewers, as above, inside the walls	3,162	. . . .	128,780
Sewers, as above, outside the walls	4,890		
From June, 1891, to 1892.			
Sewers allowing personal circulation	678	$16,120	
Sewers allowing personal circulation (smaller) . .	1,324	14,520	30,640
From 1892 to 1897.			
Sewers allowing personal circulation	2,735	$65,000	
Sewers allowing personal circulation (smaller) . .	875	9,600	74,600
Total	. . .	. . . . .	$4,072,205

The water supply is obtained from the Arno, being filtered through a tunnel called "Galleria dell' Anconella," extending in an eastward direction 20 feet below the bed of the river from the works at San Niccolo up to the Anconella for a length of 1640 yards and then raised by pumps into two large reservoirs, one to the north (Pellegrino) and the other to the south (Carraia), whence it is distributed into the town.

The maximum temperature of the water at its source is 73° 4′ Fahr.

Another supply is obtained from several springs in the valley of the Mugnone and neighborhood four miles from the town, in substitution of the old Montereggi aqueduct which once conveyed water direct from some springs which were declared to be liable to infection, and consequently suppressed in 1891. This spring water rises by natural pressure to the main up to the distributing reservoirs at 43½ yards above the level of the threshold of the principal entrance of the communal offices, and then from the reservoir it flows through pipes into the town.

An additional supply is obtained from a large well in the middle of the Campo di Marte, brought up to a third reservoir (Querce) by a 40 horse-power steam engine, pumping 11 gallons per second. This engine was manufactured by Messrs. Tosi, of Legnano, province of Milan.

The capacity of the reservoirs is as follows :

	Cubic yds.	Gallons.
Pellegrino	24,329	4,092,000
Carraia	16,742	2,816,000
Querce	5,232	880,000

The machinery of the San Niccolo works for forcing up the water into the reservoirs consists of three pairs of pumping engines raising 66,000 gallons of water per hour, moved by two turbines of the force of 170 horse-power each. The works are also fitted with steam engines for use when the river fails to supply the required hydraulic power, which generally occurs only during thirty or forty days of the year.

The pipes in use are of cast iron and manufactured in Italy.

In the year 1896 the total consumption of water amounted to 874,748,380 gallons. Up to the end of said year the total number of concessions granted for domestic use was 4834.

Nearly every house is provided with a well, of which about 13,000 exist in the town. Well-water generally rises from a depth of 29½ to 36 feet from the surface of the soil, its temperature being from 57 degrees 2 minutes to 60 degrees 8 minutes Fahr. Of late years, a few of these being reputed unwholesome, were closed by the municipality.

The quality of the public water is satisfactory under ordinary circumstances, but it is said by hygienists to be liable to become contaminated and, consequently, a source of public infection. It is also held to be decidedly scarce in quantity, chiefly to the detriment of the public services, especially watering of the streets, boulevards, etc., this scarcity being always an obstacle to the general suppression of private wells, which might eventually become a source of infection.

The question of the water supply has been a matter of discussion in Florence since 1811.

A scheme to provide water from the Sieve was sanctioned by the Grand Ducal Government as early as 1857, but the commune was obliged to give it up on account of the great cost of the enterprise.

In 1867 the municipality bought some springs at Rignalla with a view to bring their water into the town, but even in this instance the project was abandoned on account of the scarcity of water available therefrom.

Two years later a municipal commission appointed for the purpose fully reported on the matter, but nothing was done until 1870, when the Montereggi aqueduct was transferred to the commune and improved.

In 1872 the scheme for the present system (Anconella tunnel) was brought forward and met with the approval of the commune; the present works were speedily commenced and completed in 1877, their rapid completion being due, as in the case of other great public works, to the energy and good offices of Commendatore Ubaldino Peruzzi, at that time Syndic of Florence.

The supply so obtained was, however, not found in course of time very satisfactory either as to quality or quantity. A competent commission appointed in 1886, after careful chemical and bacteriological analyses, reported it to be "fairly good, but liable to contamination." The matter was therefore brought again into discussion and a new commission appointed. The latter presented in 1893 an elaborate scheme for bringing the water from the "Garfagnana" by an aqueduct 64 miles in length at an expense of about $4,000,000. The project was, however, objected to and abandoned.

The commune decided, therefore, to intrust the study of the question and of further schemes to the permanent municipal commission of works, who, having examined eight new projects, reported upon them on May 14, 1895. Of these, three only were found worthy of serious consideration:

1. Messrs. Luciani Brothers' project to obtain the water from the Monte Amiata by an aqueduct 72½ miles in length at an expense of $3,200,000, giving 5,280,000 gallons per diem (twenty-four hours).

The Board rejected it on the ground that there was no guarantee that the water was good, and that its estimated cost was too much under the mark, calculating that it might exceed $4,600,000.

2. Project of Engineer V. Bibolini; source, Pistoja Apennines; output, 6,600,000 gallons per diem (twenty-four hours); cost, $1,600,000.

Objected to for technical reasons.

3. Messrs. Vestrini and Bibilini's project for an aqueduct to bring the water from the Gangheri and Chiesaccia (Garfagnana); length, 62 miles; output, 6,600,000; to be constructed at their risk for $2,200,000.

This was preferred to the others by the Board, with some modifications. The Board, however, advised the Giunta to have tenders for the grant of the concession on the main lines of the above project, but under conditions fixed by the commune and suggested by said Board.

This project was analogous, as far as the source of supply is concerned, to that proposed by the Commission of 1893 and rejected by the commune.

A new proposal, which was said to be very advantageous for the commune, was at this time submitted by another company (Del Poggetto's project) on the lines of that suggested by Engineer V. Bibolini, for obtaining the water from the Pistoja Apennines. Obstacles, however, arose on account of the important mills existing in that district, especially at San Marcello, where hydraulic power is used up to 300 horse-power and which would have been deprived of the same, and above all on account of the practical difficulties of collecting together the water of the numerous small springs in that district.

For this and other reasons this project failed and gave way to that of Messrs. Boggio and De Niccolò, by whom at last a preliminary agreement was prepared and sanctioned both by the commune and prefecture on July 9, 1897.

The detailed technical project has not as yet been published, nor the contract signed. It is, however, held in official quarters that the company, a solid and reliable one, will be but too ready to undertake the enterprise about which they have already incurred some expenses for preliminary studies, etc.

The company will bind themselves to bring into Florence every twenty-four hours 6,600,000 gallons of drinking water of excellent quality, to be derived either from the springs of the Pistoja Apennines or from the Turrita di Galliano (from the spring called "dei Gangheri") in the "Garfagnana," will provide the springs (except that of the Gangheri, which already belongs to the commune), will make the necessary expropriations to construct the aqueduct and reservoirs, lay the mains, pipes, services, etc., all on account of the commune, which will immediately become proprietor of the plant.

The company will have the right to exploit the aqueduct on their own account for fifty years.

The commune guarantees the sale of 1,100,000 gallons of water per diem after three years of exploitation and 1,320,000 gallons after five years. This guarantee will not be binding in case of wars fought in Italy, epidemics or other public calamities. It will completely cease when the sale of water for domestic use shall have reached 1,320,000 gallons per diem.

The company will have to submit to the commune within a year from the date of the notification of the provisional concession from the superior authorities a complete plan of the plant. On receiving said concession, they will have to pay to the commune as a security $750 of 5 per cent. Italian rente.

Before the definite project is approved, the water to be brought into the aqueduct will have to be carefully analyzed by a special commission appointed by the commune in order to ascertain that the same is of the best quality and from natural springs.

The supply may be effected in two distinct periods. In the first not less than 4,400,000 gallons per twenty-four hours will have to be provided within thirty months after the date of the definite contract; in the subsequent periods the supply will have to reach 6,600,000 gallons per twenty-four hours as soon as the total consumption will be 4,180,000 gallons per diem. In this case the works will have to be completed in eighteen months. Under any

circumstances the same will have to be completed within thirty years from the date of the contract.

As an indemnity for all expenses incurred by the commune from January 1, 1897, up to the date of the execution of said contract, for laying new pipes and other unavoidable works to the mains, the company will have to pay a sum not exceeding $30,000.

The commune will grant the company during the concession the free use of the water of the spring of the Gangheri, that of the reservoirs of the Carraia, Pellegrino and Querce, and the whole plant underground. The company, with the consent of the commune will, if necessary, modify this plant at their own expense.

Whenever required, at the request of the commune, the company will construct at their own expense a reservoir of the minimum capacity of 880,000 gallons near the one existing at Querce, according to the accepted plan approved by the commune. The commune will have the right of free use for all municipal requirements of 2,200,000 gallons of water per twenty-four hours. When the quantity of water sold for private use shall have reached 1,320,000 gallons per diem, the company will have the right to use within the communal territory, but outside the gates, and exclusively for the watering of the streets, squares and other public purposes, the water of the well of the Campo di Marte, which will be placed at the disposal of the company just as it is, together with the accessory buildings and machinery. In this case the company will construct at their expense the necessary conduits, reservoirs, etc., in such a way, however, as to be entirely separate and independent from the other systems, and always subject to the approval of the communal council, and under the strict surveillance of the same.

The company will be exempt from all direct communal taxes for the construction as well as for the exploitation of the aqueduct, and from octroi duty on the pipes, etc., but not from any other tax.

The commune will be entitled to use the water obtained through special pipes laid at its expense from the tunnel of the Anconella, or from any other old aqueduct or spring, excepting that of the Campo di Marte, for the purpose of cleansing public drains, watering streets, public gardens, etc., but in no case shall the water be introduced in the mains and reservoirs used for drinking water.

The prices of water for private use shall in no case exceed the following rates :

	Per Day.		Price.
	From	To	
	Gallons.	Gallons.	Cents.
If the water is obtained from the Garfagnana by water meter . .	22	132	7.180
	154	220	6.336
	240	660	5.702
	770	1,980	5.286
	2,200	. .	4.800
By permanent flow	440	1,100	4.224
	1,320	2,200	3.840
	2,400	. .	3.072

As soon as the consumption has reached 1,320,000 gallons per day, the company will be bound to pay the commune an annual sum of $1620 for every additional 44,000 gallons of water sold per diem.

The duration of the exploitation on the part of the company, fixed at fifty years, will commence from the day on which the distribution of the water into the town for public and private use actually takes place.

The aqueduct shall be constructed of metallic pipes of Italian manufacture.

The project which has been at last selected appears to be very satisfactory in all respects. The water of the Garfagnana is of excellent quality, from deep-lying springs. Moreover, the contract will finally ensure a daily supply of 6,600,000 gallons (33 gallons per head), so that even calculating at 2,200,000 per diem the water required for watering the streets and squares of the city (total area, 2,509,708 square yards), as well as for the fountains and other services, there will still remain an abundant quantity for domestic use (22 gallons per head per diem). The city will thus enjoy a larger water supply than the cities of Manchester (21 gallons), Birmingham (21 gallons), Liverpool (22 1-5 gallons), and not much inferior to Edinburgh (39 gallons) and Dublin (36⅓ gallons).

The cost of the aqueduct is calculated at $2,200,000.

Moscow, Russia.

Moscow covers with its suburbs 40 square miles. The Moscow River, on both banks of which the city stands, remains frozen for an average of 153 days a year. Moscow is the principal industrial and commercial center of Russia, and has some 10,000 industrial establishments. The iron, steel, cotton, leather and paper industries are highly developed. The number of workmen employed in the different works is about 135,000. The annual commercial transactions of Moscow are estimated at over two thousand million rubles. The population is about 1,000,000.

The Moscow waterworks are the property of the city and controlled by the same. The first waterworks in Moscow were built in the year 1779, by order of the Empress Catherine the Great; they were built and controlled by the Government. The second waterworks were erected by the Government in the years 1854-58; they were city property, but controlled by the Government. Since 1872 all the waterworks have been controlled by the city. In the years 1891-93 new waterworks were built and a 5 per cent. loan of $2,750,000 was issued. In 1897 a loan of $1,300,000 at 4½ per cent. was issued for the addition of pipes, required for the extension of sewerage.

During the last year, 1898, the average daily consumption of water was 1,800,000 vedro, or 5,850,000 gallons. The maximum consumption was 130,000 vedro, or 422,500 gallons per hour. The consumption of water is measured by means of an automatic device by which the following data are automatically marked by a diagram on a cylinder, which makes one revolution per twenty-four hours, viz.:

(a) Every 10,000 vedro of water pumped by the engines to the reservoirs separately for every engine (P vedro per hour).

(b) Every 3 inches of water increasing in the reservoirs (B vedro per hour).

(c) Every 3 inches of water decreasing in the reservoirs (T vedro per hour).

From these three data on the diagram the quantity (Q) of water consumed in the city every hour can be ascertained: $Q = P + B - T$.

The water comes from a deep layer of coarse quartz-sand, filled by water, on a layer of yara clay. The place where the water is collected is about 10 miles from the city. It is taken from the soil by means of fifty tube wells with a diameter of 4 inches, made after the model of those used in the water supply of Brooklyn, New York. At present, and in order to increase the quantity of water, it is intended to make a new set of wells with larger diameters, also after the Brooklyn system. The source called "Mitishe" can supply 11,500,000 gallons a day; but with the extension of the sewerage the city will require about 60,000,000 gallons per day. It is therefore now projected to take water from the Moscow River, at a distance of about 100 miles from the city. The water of Moscow is very pure; but still it can only be used on condition that it is filtered. The minimum flow of the Moscow River is 200,000,000 gallons per twenty-four hours.

The water taken by suction at "Mitishe" is pumped through a 24-inch main 45,230 feet long into a brick-covered reservoir at "Alexievskoie," whose capacity is now 1,000,000 gallons, but in 1899 it will be increased to 3,250,000 gallons. From this reservoir the water is pumped into two distributing reservoirs, each having a capacity of 325,000 gallons, from which the water is sent by gravitation to the consumers. The last two reservoirs are made of iron and situated in brick water towers 130 feet high.

Until the year 1834 there was a gravitation system, the water flowing from "Mitishe" through a covered brick canal 40 miles long, with a decline of 1 in 3500. But afterwards this system was changed into a pressure system.

Up to the year 1858 there was but one pumping station, but at that time two pumping stations commenced to work.

From 1893 there have been two new pumping stations in operation, "Mitishe" and "Alexievskoie." These stations pump the water into the reservoirs of distribution, from which it flows by gravity to the consumers.

Each of the two pumping stations "Mitishe" and "Alexievskoie" has three triple-expansion horizontal steam pumps, provided with Bidler valves. Each of these six engines has a capacity of 5,000,000 gallons per twenty-four hours. The pumping station "Mitishe" can raise water under a dynamical head equal to a column of water 100 feet high. The pumping station "Alexievskoie" raises water under a dynamical pressure of a 165-foot column of water. At each of the pumping stations one engine is always at work, while two are in reserve (one of which can be dismounted for repairing, etc.). Naphtha is used as fuel; 4,000 kilograms are consumed per twenty-four hours at both stations, the price of naphtha being 20 rubles, or about $10 per ton. Naphtha produces no smoke if there is enough air.

The pressure in the boilers is 150 pounds per square inch. The boilers

are similar to the Babcock & Wilcox system. The water gives but very little crust, the tubes of the boilers being cleaned once a month. There are three boilers in every pumping station, one being always at work and two in reserve.

The pumping mains are of cast iron. From the pumping stations of "Mitishe" to "Alexievskoie" there is a cast-iron conduit of a diameter of 24 inches. From "Alexievskoie" to the "Krestovsky" reservoir it is a 24-inch conduit. During the present year, 1899, a second conduit of a diameter of 30 inches will be provided. The pipes in the city have diameters ranging from 4 inches to 28 inches. Their length is now 100 miles. At the end of 1899 about 120 miles will have been added; they are to be from 4 inches to 9 inches in diameter.

The distributing reservoirs are of two kinds: the first for 1,000,000 gallons is situated at the pumping station "Alexievskoie." It is made of masonry, with vaults, and covered with a 42-inch layer of earth to prevent the freezing of water during winter and the warming of water in the summer. From this reservoir the water is pumped into two elevated iron reservoirs situated on two masonry water towers at the entrance of the city. Each reservoir contains 325,000 gallons, and is at a height of 110 feet above the surface of the ground and 225 feet above the water line of the Moscow River. The water flows into both reservoirs through vertical 24-inch cast-iron pipes. The cost of the "Alexievskoie" reservoir was $75,000, and that of the "Krestovsky" reservoir $300,000 (towers included). During six years these reservoirs have not required any repairs, and their maintenance has not required any substantial expense. The reservoirs have shown no leakage.

All pipes (main and branch) are of cast iron and have diameters ranging from 4 inches to 28 inches. Pipes in the houses are also cast iron and have a diameter of 2 inches. All connections are of the American type. All pipes are tested at the foundries by a pressure of 300 pounds to the square inch. After being laid in the trenches and covered with earth they are again tested at a pressure of from 150 to 225 pounds. When the pipes are received from the foundry, the thickness of their sides is measured by a special instrument (Kroncircle). If the pipe is in any spot 20 per cent. thinner than normal, it is rejected. Such a method of receiving pipes is of great importance and can be recommended. The leakage from pipes owing to the form of joints is insignificant. Safety valves are affixed to each house connection. The cost of the valve is 8 rubles, or about $4. The cost of the mains for distribution is $820,000.

All service pipes are of cast iron. They are laid in the same way as are the mains. The breakage of pipes caused by water hammers is prevented by safety valves, which are put one on every 2 versts (1 mile = 1½ versts).

Service pipes leading water from the mains into houses have a diameter of 2 inches, and are of cast iron as far as the house water meter. These pipes are made by the city at the expense of the house owner. In the street repairs are made by the city, and in the houses by their owners. The pipes are controlled by the city, only as far as the water meter. The arrangement of the water supply inside the houses is left to the consumers and the city does not control them, as water is given exclusively through water meters.

Water is delivered to the consumers in a daily average quantity of about 6,200,000 gallons, and is sold to all for the same price of 1.88 cents per 100 gallons. The loss of water is not extensive, inasmuch as street mains are tested under a pressure of 10 atmospheres, and in the houses the water consumption is checked by meters, the use of which is compulsory. The meters belong to the city, the rent paid for same by the consumers being equal to about 10 per cent. of their cost. The meters are maintained by the city. No measures are taken to prevent too great economy of water. The control by water meters costs the city about $2.50 for each water meter per year. For the inspection of 1200 meters, four men are employed; there is besides one man for the inspection of forty-five water meters at the public water distributions.

The spring water of the waterworks is of the following hardness (German scale):

Total	8.48
Permanent	4.00
Temporary	4.48

The water is colorless, of high purity, and very good for drinking. No measures for the purification of the water are taken as long as they are not necessary. There are now in the water after passing the reservoirs about twenty-five bacteria per cubic centimeter and .0064 parts of organic matter per 100,000 parts of water by weight. The temperature of the water in the winter as well as in the summer is about 5 degrees Réaumur. The pipes are 8 feet deep in the ground. For the future larger water supply it is intended to take water from the Moscow River, which water will be filtered.

Sedimentation is not required.

There is no aëration nor filtration of any kind.

No mechanical filters are used as yet, but an experimental filtering plant of mechanical filters is being arranged by which experiments will be made by three systems of filters—with the "Jewell" and the "Warren" gravitation systems and the "Bidell" pressure system. These experiments with mechanical filtration are necessary for the future river water supply. The European slow sand filters are well known in Russia; a satisfactory installation of them in that country costs 40 to 50 cents per 3.25 gallons of daily capacity (filters for 1,000,000 gallons per day cost from $120,000 to $160,000). Mechanical filters cost from five to six times less, and according to tests already made give quite satisfactory results. The Moscow engineers are of the opinion that no great city ought to adopt the European system of slow filtration without having previous experiments with the American system of rapid filtration. It must be remembered that there are very many cases in Europe where slow filtration gives unsatisfactory results. In St. Petersburg, for instance, European sand filters remove from the water only about 60 per cent. of bacteria.

Analyses of water are made by a sanitary station at the Institute of Hygiene of the University of Moscow. The water is soft and contains few bacteria.

Special apparatus for the direct extinction of fires are not used. There is, on an average, a hydrant on every 350 feet of water main. The hydrants are of the type used in Boston, Mass., and Providence, R. I., with slight modifications. Their diameter is 5 inches. The mains are so planned that, without interfering with the domestic water consumption, it is possible to obtain from hydrants in three different places of the city 650 gallons per minute each—that is, in all, 1950 gallons per minute. In low places of the city, where the pressure is more than 4 atmospheres, fire hydrants are used without fire engines, and in high places of the city hand and steam fire engines are used.

Stand pipes are not in use.

Water motors are as yet but very little used.

Piston water meters are used exclusively, being of the following systems: Kennedy, Frost-Favene, Schreiber and Frange. The last system is the most used. Reacting or turbine meters are not used at all.

In the year 1897 the receipts for metered water amounted to $270,000.

The charges made for the meters are as follows:

	Per Month.
½ inch	$0.25
⅝ "	0.40
¾ "	0.50
1 "	0.60
1½ inches	1.20
2 "	1.50

The expenditure for the Moscow waterworks with a capacity of 5,200,000 gallons per twenty-four hours and with eighty miles of main was $2,750,000.

The maintenance of the waterworks costs, per year, $125,000.

The amortization of capital is given at $150,000.

The salaries of the waterworks officers are as follows :

		Per Year.
Chief engineer		$5,000
Four assistant engineers	each from $1,000 to	3,000
Eight machinists (engineers)	" 250 to	600
Five controllers	" 450 to	600
Twenty whitesmiths	" 200 to	400
One hundred and sixty workmen	" 90 to	150

Most of the officers also receive free lodgings from the city.

Higher officers are appointed and discharged by the chief engineer and confirmed by the City Councils; lower officers are appointed and dismissed by the chief engineer and his assistants.

The existing spring supply is to be increased from 5,200,000 gallons to 10,000,000 gallons per day. It is, besides, the intention to build a separate river water supply system of a capacity of 45,500,000 gallons. These second works are to be commenced in the year 1900. The central part of the city will then be supplied with spring water, and the outskirts by filtered river water.

Vienna, Austria.

Vienna (German "Wien"), the capital of the Austro-Hungarian monarchy, is situated on the right bank of the Danube, at its confluence with the little River Wien at the west end of the level plain known as the Marchfeld. The importance of the geographical position of Vienna consists in the fact that it lies on the spot where the last northeast off-shoots of the Alps (Wiener Wald) reach the Danube plain.

Vienna is the industrial and commercial center of Austria. The chief manufactures are machinery, musical instruments, ironware, jewelry, surgical and physical instruments, beer, chemicals and leather goods.

Vienna is the fourth largest city in Europe, outranked only by London, Paris and Berlin.

Its population is about 1,500,000.

Up to the year 1873 seven public and eight private water conduits supplied the city with water. The most important among the first named was the Kaiser Ferdinands Wasserleitung (Emperor Ferdinand Waterworks), which received filtered water from the Danube Canal, near Heiligenstadt.

In 1873 the Kaiser Franz Josephs Hochquellenleitung (Emperor Francis Joseph's High Well Works) were built at a cost of $11,040,000. These works, which are the property of the city of Vienna, are controlled by the Mayor and the respective Councils of the different departments of the city administration.

The consumption of water reaches its maximum in the month of August and the minimum in February of each year; the maximum consumption being 3,799,250 cubic feet, the minimum 2,376,850 cubic feet, and the average consumption 3,269,000 cubic feet.

From 175,000 to 3,140,000 hectoliters of spring water are daily brought through a conduit about 50 miles long from the district of Schneeberg (Kaiserbrunnen, 1196 feet; Stixensteiner Springs, 913 feet above the Danube) to the city. The conduit has thirteen galleries and five aqueducts. It takes the water twenty-four hours to run from the source to the powerful reservoir near the Rosenhuegel, which is situated 288 feet above the Danube.

In order to increase the capacity of the works a new pumping station was built in 1878 at Pottschach, by which about 160,000 hectoliters of water are daily brought into the aqueduct.

The pipes are laid at such a depth that their surfaces are covered by 5.24 feet of earth.

The network of distribution pipes for the different parts of the city has been constructed on the circulation system, and the mains are connected in several parts by means of separating valves, in order that the system may afford combinations in case of breakage.

The different connections between the pipes in the streets and the water meters in the interior of the houses are mostly made of .97-inch sulphur-covered lead pipes, which are installed by the city of Vienna at the expense

of the consumer. The connections in the houses are made by builders holding a license from the city for work of this kind.

The only water taxes collected are those indicated by the water meters.

The quality of the water is such as to satisfy all demands that can be made for good drinking water.

The insignificant sediment in the reservoirs is removed by cleaning out from time to time. The rinsing out of the service pipes takes place as necessary by means of water valves laid in the lowest parts of the city.

No special arrangements are made for aëration.

Owing to the quality of the water, filtration is not necessary.

The water for fire supply is drawn from the so-called surface hydrants of the streets, either directly or else the supply is taken to the place where the fire is by means of portable engines or special water carts.

The number of hydrants is almost 1200. The cost of these hydrants, exclusive of the cost of mounting and connection pipes, is $40.80.

The use of water motors is not allowed.

Hydraulic elevators may not have a direct connection with the waterworks, but they are fed by means of a reservoir located on the roof. Lately, electricity has been employed to work these elevators.

No changes are projected in the system of water supply. The pure and clear water which reaches Vienna from the mountains makes any installation for purifying it unnecessary.

Since the installation of the waterworks in October, 1873, it has been shown by public reports that the general state of health has improved. Typhoid fever cases especially have almost disappeared. With the extension of the water service in 1891 public hygiene has also very much improved.

The more detailed regulations of the Vienna waterworks may be summarized as follows :

Water for drinking and domestic use is only served to owner of the house.

The average quantity necessary and sufficient for the use of each resident of a house is supposed to be 6.5 gallons per day ; nothing less than 132 gallons per house, however, can be supplied.

The service pipes are established by the employés of the municipality according to law. The costs thereof have to be repaid to the municipality two weeks after receipt of bill by the proprietor. After this term has expired, interest at 6 per cent. is charged on the amount unpaid.

The service pipes become the property of the party who uses them and who has paid the costs thereof.

The quantity of water consumed is ascertained by means of a water meter. These water meters are installed at the expense of the municipality, the proprietor of each house having to pay certain taxes to the public treasury for the use of them. These taxes are as follows :

	Per Year.
For a meter of .39 inch to .5 inch	$2.40
" " .97 "	4.80
" " 1.56 inches	7.20
" " 1.95 "	9.60

In the case of a meter having been installed during the quarterly term, the taxes are collected for the whole quarter. The piping for the interior of the house can be installed by the proprietor either by having the work done by the municipal contractor, or else by plumbers holding a license for such work and acting under instruction from the municipal authorities.

The pipes employed for the water service of the houses must at least have the following weight:

						Pounds.
A lead pipe	.5	inch in diameter	for each	39.37	inches run	6.16
"	.78	"	"	"	"	9.9
"	.97	"	"	"	"	15.9

In case a diameter of more than .97 inch is required, cast-iron pipes may be used.

The pipes must be laid at a depth of at least 5.85 inches from the outer walls of the houses, to keep them from freezing.

Any proposed changes in the water service of the house must be first submitted to the authorities.

Fire cocks may be established in the interior of the houses at the expense of the applicant. The owners of these fire cocks have to pay a certain tax to the municipality, the price being for one cock in the house $2.20 a year, and for each additional cock 50 cents a year. The fire cocks are fitted according to instructions of the municipalities and are secured by means of lead seals which may only be removed in case of a fire.

The employés of the water service must at all times have access to the places where the conduits and meters are.

For extraordinary use, that is for more than 6.5 gallons daily for one person, and for industrial purposes, the necessary water is supplied under special agreement.

Water for building purposes is only given out at a fixed number of gallons.

The water for extraordinary use and for industrial purposes, with the only exception of that used in building, must be obtained through a meter.

The proprietor of each house to which water is supplied is charged for a daily supply of 6.5 gallons a head, $1.20 a year, besides the yearly cost of maintenance.

One dollar and ninety-two cents per year per 26.41 gallons is paid for water used for extraordinary and industrial purposes, besides a yearly cost of operation and maintenance.

For the water consumed above the quarterly allowance, inclusive of the 10 per cent. allowed for extra use, or the quantity allowed for extraordinary and industrial purposes, 96 cents per 26.41 gallons is charged.

Payments for expenses of operation and rents of water meters have to be made quarterly in advance.

Munich, Germany.

Munich (German "München") is the capital of the kingdom of Bavaria. The city lies in a monotonous plain on both banks of the Isar River; but the Bavarian Alps, with their grand scenery, rise not far from the town. Munich is one of the industrial centers of Bavaria. Beer-brewing has to be mentioned first in this respect, enormous quantities of beer being annually produced. Moreover, the manufacturers of jewelry, gold and silver articles, iron and brass castings, machinery, leather goods, and optical and mathematical instruments are of great importance. The population is about one-half million.

The waterworks of the city of Munich belong to the municipality.

The daily consumption in 1898 was as follows:

	Cubic Feet.
Maximum consumption in twenty-four hours	3,395,000
Minimum " " "	2,520,000
Average " " "	2,800,000

The consumption is ascertained by overfall colleries in the various conduit installations and by observing the height of water in the upper reservoirs.

The sources of supply are found in the promontory of the Alps at an average height of about 330 feet above the city, and at a distance of from 25 to 28 miles.

There is one upper reservoir with two compartments, with a depth of water of 11.79 feet and a total capacity of 1,312,500 cubic feet.

The water is conveyed to the various distributing centers in the city by means of gravity.

The system consists of two colleries, with a double service of pipes, and, for cutting through valleys, cast-iron sewer pipes. The cost of maintenance amounts to about $2400 a year.

The total costs for the installation of the pipe service amounted to about $1,430,000. The works, including lands purchased, are valued at about $38,700, in expenses hitherto incurred. The cost of maintenance and other expenses is about $3570 a year.

There are three main pressure-pipe lines, two of which are 27.3 inches in diameter and one 31.2 inches in diameter.

The service pipes consist for the greater part of cast-iron flange pipes, the remainder consisting of forged-iron flange pipes.

Pipe lines of a greater dimension than 13.6 inches have conduct tracks. The smallest diameter of pipes used for the distribution mains is 3.9 inches. Pipes of a diameter of 3.12 inches are only used as conduits for hydrants. The connection of the flange pipes is made by means of so-called check cords and lead. The flange pipes are also connected by screws with insertion of india-rubber disks. In the case of breakages, arrangements are made for the speedy attention to such an accident, by means of special watchmen, who

always have a wagon with the requisite men and necessary tools at their disposal. There are as yet no signs of the service becoming worn out in any way.

The service pipes are of lead, .7 inch to 1.4 inches in diameter. From 1.9 inches upward they are made of cast iron. The pipes are the property of the respective owners of the tract on which they are laid; but they are laid and maintained by the municipality, the owner paying the costs thereof. The installation of the service in the houses is a private undertaking.

The consumption of water is not restricted in any way as to the amount consumed, the water being abundant and the consumption being paid for. Water meters are almost universally used, but their use is not compulsory. The water taxes are paid either according to gauge or to water meters. The water meters are the property of the municipality.

They are under the regular control of the authorities and the taxes are collected in accordance with the rents, the amount of which is determined by the size of the water meter and fixed according to the regulations on water service.

The regulations on the use of water are such that the smallest meter will be sufficient for the amount of water wanted, and therefore no other means of preventing undue economy in the use of water are employed. The yearly expenses for the installation of water meters are about $4800.

There is no necessity of improving the quality of the water.

The chemical and bacteriological examinations of the water take place every year by the officials of the Royal Institution for the Inspection of Foods and by the Royal Institute of Hygiene of Munich.

The supply for fire is drawn from the general supply. The service contains, up to date, 2326 subterranean hydrants, which are brought into action by means of stand pipes.

The stand pipes are provided with two issues, and are joined to the hydrants by means of so-called Bajonet screw joints with leather backings, the connection with the hose lines being made by conus cocks and screws, or Storz screws. The stand pipes have 2.53 inches C. W. The conus cocks as well as their screws (formerly called Metz, latterly Storz screws) are of 1.7 inches diameter.

The stand pipes are about 23.4 inches in height; the pipes are mostly made of copper and the cocks of brass.

The fire hydrants are at a distance of about 260–330 feet; they are placed in the sidewalks, and their joints, spindles, etc., can be reached by means of iron caps.

MOTORS AND HYDRAULIC ELEVATORS.

Up to the end of the year 1896 the municipal waterworks were connected with seven motors of an aggregate capacity of 1,267 horse-power.

	Pounds.
24 passenger elevators with a capacity of	18,953
127 freight elevators " "	105,685
Total: 151 elevators with a total capacity of	124,638

Since then one freight elevator has been withdrawn of a capacity of 440 pounds, thus giving a total of 150 elevators with a total capacity of 124,198 pounds in actual operation.

WATER TAXES.

The price for water is 5 pfennige, or 1.2 cents, for 1 cubic meter (35 cubic feet); the taxes for a temporary use of water, such as for building purposes, shows, etc., being 7.05 pfennige, or 1.6 cents. The minimum consumption is generally 70 cubic feet daily, and the taxes amount to $9.56 yearly.

For very small establishments the municipality allows, upon special application, the quantity of only 35 cubic feet to be granted at the price of $4.78 a year. For every additional cubic meter (35 cubic feet) consumed $4.78 a year is charged.

If taxes are collected according to water meters, a minimum quantity of water is fixed in proportion to the size of the meters, and this quantity has to be paid for, even if the whole of it is not consumed. The minimum quantities and minimum taxes of water are arranged as follows :

Water Meter.	Minimum Quantity of Water.	Minimum Taxes for Same.
Inches.	Cubic Feet.	
.2	35	$4.78
.5	70	9.56
.7	175	21.42
.98	350	42.84
1.2	875	107.10
1.4	1,750	214.20
1.9	2,800	342.72
3.1	3,500	428.40
3.9	5,250	642.60
4.8	8,750	1,091.20
5.8	14,200	1,752.00
6.7	21,500	2,628.00
7.8	29,750	2,722.00

The consumption of water exceeding these minima, as indicated by the meters, has to be paid for separately, at the rate of 5 pfennige (1.2 cents) each cubic meter (35 cubic feet).

Double taxes have to be paid for water consumed outside of the limits of the Burgfrieden of Munich.

The water examined contained on an average the very small number of eleven germs to each cubic centimeter.

No pathogenic bacteria were found.

The water of the waterworks of Munich may therefore at the present time be called exceedingly pure, from a bacteriological standpoint.

Frankfort-on-the-Main, Germany.

Frankfort-on-the-Main is the commercial metropolis of South Germany. It is the center of several railroads, and one of the richest towns on the Continent. The population is about 240,000. The Prussian Parliament has lately voted a large sum for enlarging the River Main from Frankfort to Mayence, and so making it accessible for the largest Rhine steamers.

The water supply of Frankfort is drawn from several sources, according to the need to be supplied. Drinking water and that used for household purposes is drawn from springs; water for street sprinkling, for the extinguishment of fires, for supplying the fish ponds of the parks, and for the use of the public slaughter houses and stockyards, from the River Main by means of a pumping station located on its left bank.

The history of the attempts to secure a sufficient amount of water to supply every public need is an interesting one.

Beginning as far back as 1834 the spring water of the Friedberger field was piped to the town. This proving insufficient, the water from the Seehoff springs was added in 1869. There still being a deficiency, in 1870 a private company was formed to conduct the water from other springs on the Vogelsberg, and from those in the Casselgrund and Biebergrund in the Spessart. This further increase to the water supply was put in working order in 1873.

Up to this time the work of installing the various water plants had been in the hands of private companies. In 1876, however, the whole of the work completed up to that time passed into the control of the municipality, where it remains at the present time.

In 1881 springs from the Riederspiess were added.

In 1885 further additions of water were found necessary, and met by tapping the deep springs of the wood belonging to the public domain of Frankfort.

About the same time was built the pumping station on the left bank of the Main, already referred to.

At the present time, therefore, the supply is drawn from the above-mentioned springs, so connected as to make their water available, and from the Main.

COLLECTION OF SPRING WATER.

In the case of the Friedberger springs, their water is led by a system of walled conduits, of a combined length of 3048 feet, into a hollow of the Friedberger and Knoblauch Fields, lying north of the town.

Their capacity is 16,800 cubic feet every twenty-four hours. The water is drawn from this natural reservoir by a cement pipe 9.24 inches in diameter to the city pipe system, to which it is connected at the Fuersteneck. The water from the Seehoff springs, situated on the left bank of the Main near the road over the Sachsenhaeuser Hill, is pumped into a small reservoir, whence it is piped into a larger walled and covered one having a capacity of 54,250 cubic feet. From here the water is pumped by two steam pumps of 28 horse-power, through a main of 2650 feet in length, with a diameter of 9.24 inches, into a reservoir lying 432 feet higher and having a capacity of 26,250 cubic feet. From this high reservoir the water is conducted by means of conduits 9.4 inches in diameter to the old pipe system of the Friedberger springs, which, as noted above, joins the main service pipe system of the city at the Fuersteneck. The capacity of the Seehoff springs is about 42,000 cubic feet daily. The production of the springs on the Riederspiess is from 38,500 to 45,500 cubic feet per twenty-four hours. This water is forced, by means of two steam pumps of 36 horse-power, through a conduit 9242 feet in length, with a diameter of from 9.75 to 11.7 inches, to the principal supply reservoirs receiving the spring water, lying at a height of 205 feet above it. In being raised to this height, two suction pumps draw the water into an intermediate receptacle, from which the force pumps raise it as above described.

VOGELSBERG SPRINGS.

These springs consist of many small ones, divided into four groups, all lying in a depression of the valley. Each spring is walled in to prevent access of surface water. Their combined flow, amounting to 308,770 cubic feet per twenty-four hours, is collected by cement pipes, 16 inches in diameter, into a water chamber, from which the water is conducted to a supply reservoir at Birnstein. From here it is piped to the supply reservoir at Aspenhainer Kopf by a pipe line 55,265 feet in length, having a diameter of 14.04 inches. The combined length of the cement pipes collecting the water of these springs is 10,624 feet. They range in diameter from 7.8 inches to 11.7 inches.

SPESSART SPRINGS.

The water from the Spessart is obtained from two distinct spring districts entirely separated, the Casselgrund and the Biebergrund, having a combined capacity of 284,260 cubic feet per day (twenty-four hours). The water from each spring district is collected by a cement pipe system, laid at least 6.6 feet under ground, of a combined length of 305,811 feet, and having a diameter of from 2.32 to 7.02 inches. The water from the two valleys is joined by means of tunnels, 5.8 feet square, through the ridge which separates them, and is then carried to Gieserborn, whence it is in turn conducted, by means of an iron pipe 24,756 feet in length and 20.7 inches in diameter, to a reservoir on the Aspenhainer Kopf. In this distance the difference in level amounts to 33 feet. The greatest pressure on the pipe is 12 atmospheres (180 pounds). The pipe crosses two small streams, the Bieberbach and the

Kinzig, going under the latter by means of a tunnel 52 feet in length. It is flushed and emptied by means of outlets 11.7 inches in diameter, placed at the lowest points. The pressure is controlled by two manometers placed in watch booths along the route. From this supply reservoir a main pipe line, 149,576 feet in length, having a fall of 2.16 feet per 1000, conducts the water to the principal supply reservoir on the Friedberger Warte. This line is continually watched by a superintendent, having three overseers and nine watchmen under his orders.

The total reservoir capacity here is 910,000 cubic feet. From this supply reservoir the water is introduced into the pipe system of the city. The supply from the deep wells of the public woods comes from a gravelly stratum from 90 to 180 feet below the surface, and amounts to about 245,000 cubic feet per twenty-four hours. The water is secured by a row of well pipes 1.9 inches in diameter. These are sunk into the stratum and their outlets connected with suction pipes. The lower end of each well pipe sunk in the earth is supplied with copper suck pipes, closed at the end, but filled with small holes, covered in turn with copper gauze to strain the water.

Ten such rows are placed in an area 2,300 feet by 25 feet, and their combined water collected by suction pipes 3.12 inches in diameter in a suction chamber, whence another suction pipe 4.08 inches in diameter conducts the water to the main suction pipe of the collecting cistern of the well water. This is accomplished by two engines of 40 horse-power, each working two centrifugal pumps. One pair of pumps draws the water directly from the main suction pipe and forces it to the other pair, which in turn forces it into the main force pipe. Of the combined height of 130 feet to which the water is raised, each pump does half. The pumps work with 700 rotations per minute, and utilize about 30 per cent. of their estimated capacity. Each pair of pumps has an actual capacity of from 105,000 cubic feet to 132,500 cubic feet per twenty-four hours.

The main conduit through which these pumps force the water is 14,025 feet in length and has a diameter of 23.4 inches.

The highest points are supplied with automatic air valves; the lowest with emptiers.

This main empties into the reservoir at Sachsenhausen, whence the water is introduced into the pipe system of the city. The total cost of this part of the system was $214,200. The water pumped from the River Main for use in the sprinkling, etc., amounts to about 43,000 cubic feet per twenty-four hours. The combined amount available is 1,534,000 cubic feet per twenty-four hours.

The reservoir on Aspenhainer Kopf, serving to contain the united spring water from the Spessart and the Vogelsberg, is composed of two water compartments and two valve compartments. Each of the water compartments has an outlet pipe 3300 feet long to the Kinzig; also overflows.

From the water compartments the water is conducted by a main 149,536 feet in length, 20.7 inches in diameter, to the main reservoir on the Friedberger Warte at Frankfort, lying at a level 323 feet lower. The fall is 2.16 feet per thousand.

This main is carried over a hill 230 feet in height,—the Abtschecke,—on

the summit of which a water-power has been erected. This has been done in order that, in case of a break in the pipe, the upper and lower parts would be independent, and in this manner the pressure on the pipes be lessened. In the middle of the water tower is a stand pipe 48 feet in height, a continuation of the inlet and outlet pipes.

In the pipe line there are nineteen air valves, working automatically, twenty-one outlet cocks 11.7 inches in diameter, and twelve safety valves.

Besides these, there are several Feder manometers and three mercury manometers for controlling the pressure. These latter are provided with electric alarms, which call attention to any decrease in pressure owing to a leak in the pipes. From the water tower the conduit pierces railroad embankments in three places. Four streams are crossed by as many little iron bridges, the pipes being here specially protected.

The main first empties into the Seckbach water compartment, from which it is conducted by a walled canal 2200 feet in length to the Friedberger Warte reservoir. Here it first enters a water compartment, is then conducted by a conduit 27.8 inches in diameter to fore-valve chambers, whence by a pipe 23.4 inches in diameter it goes into the reservoir proper. This is built in compartments and has a capacity, as already stated, of 910,000 cubic feet. The compartments are divided by partitions 105.6 feet in length and 10 feet in thickness; they are connected by openings 10 feet in width, and in this manner the movement of the water in its outflow is controlled.

For supplying the northeastern part of the city lying at a higher level than the rest a gallery 2448 feet in length leads from the fore-valve rooms, and through this a main 19.5 inches in diameter conducts the water to that part of the city. Each compartment of this reservoir is supplied with an overflow and emptying vent, and with indicators showing the height of the water. After running through the reservoir the water arrives at the compartments opposite its place of entrance, where vents are supplied to let out the air and to facilitate the overflow of the surplus water.

Ventilators insure the continual freshness of the water in the reservoir; its outlet is 432 feet above the city.

The reservoir in Sachsenhausen is connected with that on the Friedberger Warte by the main pipe line. The outlet is 16 feet lower; it is divided into ten compartments similar to those above described. Two surplus vents in the valve chamber control the entrance and exit of the water. The main to this reservoir is 19.5 inches in diameter. Each compartment is separate, and can be emptied individually. It serves to receive the water from the city wood, and has a capacity of 215,310 cubic feet.

Both reservoirs are built with walls of sandstone, arched, and have bottoms of brick laid in cement mortar. They are covered on the inside with cement.

At present the service-pipe system of the city has a combined length of 130 miles 792 feet, devoted entirely to supplying spring water. The pipes range from 1.95 to 23.5 inches in diameter, and are composed chiefly of iron. Where several meet, valve chambers, vertical or horizontal, are put in, in walled shafts. These serve as outlets and emptiers for the pipes running into them.

Hydrants and taps may be attached to supply pipes over 9.7 inches in diameter, which conduct the water to separate districts of the town. This is usually done by attaching the hydrants to offshoots from the main pipe line. Each street is supplied from a separate valve. The street hydrants are supplied with two hose connections 1.95 inches in diameter.

Part of the hydrants empty automatically into the neighboring sewer sinks, and part empty by hand into safety channels alongside the hydrants.

The Dehne system of underground vents is used in the taps. The entire cost of installing this system was $2,632,508.

In addition to this, there are almost 20 miles of pipes supplying river water.

The Seehoff spring, with its pumping station, is rented for $5405 a year to the Frankfort Beer Brewing Company.

The water from the Knoblauch springs is rented to private parties; that from the Friedberger Field is used in flushing sewers.

In 1896-97 the greatest consumption of water amounted to—

	Cubic Feet.
Maximum (July 14th)	1,375,570
Minimum (December 13th)	656,740
Average	1,001,315

By the use of water meters, of which the pipe system contains 2238, the loss of water by wasting and by hidden leaks has been greatly reduced. These meters range in diameter from .2 to 7.8 inches, and belong to the municipality.

The use of river water in 1896-97 for factories, private gardens and public buildings amounted to 77,633,955 cubic feet.

Water is supplied to private consumers as follows:

A written application, stating what is desired, is submitted to the proper city official; if no objection exists, the necessary connections are put in by the city at the expense of the consumer; these connections then belong to the city, which keeps them in repair without further expense to the consumer. The inner house piping must be put in at the consumer's expense, after the plans therefor have been submitted to and approved by the municipal authorities.

In order to prevent damage from frost, each consumer is compelled to put in shut-off cocks and emptying vents outside the front wall of the house.

The required weight of inside pipes per each 3.3 feet of length is as follows:

	Pounds.
.3 inch in diameter	3.3
.6 " "	6.6
.7 " "	9.9
.9 " "	14.3
1.1 inches "	24.2

Over 1.1 inches in diameter the pipes must be of cast iron, painted inside and outside; for warm water, galvanized pipes of wrought iron, copper or brass pipes, must be used.

The rents are gauged either by the rental value of the property or by meters, at the option of the consumer, viz.:

In the former case $0.238 is charged for each $5.95 yearly rental. Dwellings which have a yearly rental of $60 or less pay no water rent.

For business purposes the rent is $2.38 per each $238 rental value, with an additional $0.23 for each increase of $23.80 to $57.60 in the yearly rental value of the property. The price of water is, by meter, from April to September, $0.057 per 35 cubic feet; from September to April, $0.035 per 35 cubic feet.

When the necessary consumption is more than 17,500 cubic feet of water, as in factories, etc., these prices are, from April to September, $0.035, and, from September to April, $0.023 per 35 cubic feet.

The entire receipts of water rents in 1896-97 amounted to $426,012. The expense of operating the system during the same year was as follows:

Director	$2,380
Inspector of motive power	1,357
Chief engineer	1,288
Three assistants (total)	2,507
Superintendent of supply-pipe lines, assistants and other employés	3,220
Total for employés	$10,732
All other expenses	101,771
Grand total	$112,503

Geneva, Switzerland.

Geneva (French "Genève") is the capital of the Canton of the same name in Switzerland, situated 85 miles southwest of Bern, on the Rhone, at its outlet from the western extremity of the Lake of Geneva. The Rhone divides the town into two parts. The principal manufactures are watches, musical boxes, chronometers, mathematical instruments, jewelry, cutlery and firearms. The population is about 65,000.

The Lake of Geneva has a length of 45 miles, and its breadth varies from ½ mile to 9 miles. The lake is traversed by the Rhone from east to west, and receives the Dranse, Venoge, and other small rivers. Owing to the superior density of the Rhone water to that of the lake, the river at once sinks on entering, and has hollowed out a subaqueous bed, which has been traced near the south shore of the lake for nearly 4 miles. Its waters have a peculiar deep-blue color, are transparent, and contain a great variety of fish. It is never wholly frozen over, and is subject to seiches, or remarkable risings of from 1 to 4 or 5 or even 6 feet, which are explained by Forel as due to a long or a progressive wave being reflected from the shores of the lake, and giving rise by interference of the primary and reflected waves to stationary or oscillatory waves. Observations made at Vevey have shown that the rise and fall on such occasions indicate two regular oscillations, the

duration of the quicker of which is about 35½ minutes, that of the longer nearly twice as long. The original wave is ascribable to some local shock, such as a sudden gust of wind, a landslip or avalanche, or an earthquake. The greatest seiches are observed when the atmospheric pressure is low and variable. The banks of the lake are highly picturesque—the south bold and lofty, the north undulating and richly cultivated. Steam navigation was introduced on it in 1823.

The waterworks of Geneva are under the jurisdiction of the municipality. The consumption of water is ascertained either by meters or by gauges.

The daily consumption during the year 1897 was as follows:

	High Pressure. Cubic Feet.	Low Pressure. Cubic Feet.
Maximum	5,817,700	1,517,500
Minimum	1,652,315	497,700
Average	3,005,800	1,341,800

These figures are positive and are ascertained by the number of rotations of each pump, which are indicated by means of the meter multiplied by amount shown at each rotation.

The water comes from the Lake of Geneva; that used for drinking purposes being taken at a distance of 3280 feet outside the harbor jetties.

There are consequently no feed reservoirs.

The water under pressure is obtained by means of pumps. None is furnished by gravity.

The pumps are double action, of the Girard type, coupled in groups of two at 90 degrees, and worked by means of reacting turbines (Jonval system) in the following manner:

Two groups at low pressure, lifting 157½ gallons of water at each rotation to a height of 164 feet;

Three groups at high pressure, raising 54 gallons of water at each rotation to a height of 459 feet;

Thirteen groups capable of working at either high or low pressure, though generally working at high pressure, and lifting 92 gallons to a height of 459 feet.

The speed of these pumps is from 26 to 33 rotations per minute.

SERVICE MAINS.

The pipes leading to the reservoirs of distribution are composed of—

(a) For the high pressure, 4421.3 feet of pipe of a diameter of 19.6 inches, and 12,903 feet of pipe of a diameter of 23.9 inches.

(b) For the low pressure, 5469 feet of pipe of a diameter of 19.6 inches.

All these pipes are also used for distributing the water.

DISTRIBUTION RESERVOIRS.

These reservoirs have cemented stone walls, are covered with earth, and are two in number, with—

(a) One reservoir for low pressure, situated on the Bessingen Hill, depth 19.6 feet, capacity 437,500 cubic feet, the bottom being 406 feet above the surface of the lake. The pressure of the water is used again by means of a centrifugal pump regulator.

(b) One reservoir for low pressure, in the Batie Woods, depth 13.1 feet, capacity 161,000 cubic feet, the bottom being 151 feet above the level of the lake.

The stonework of these two reservoirs is covered on the inside with a strong coating made of cement. There are no leakages; the water enters into the upper part and flows out from the bottom. The system of pipes is provided with sluices, and, besides this, the reservoir of Bessingen has a clack valve which closes automatically in the event of a breakage in the pipes.

PIPES FOR DISTRIBUTION.

These pipes are of cast iron 9.8 feet in length up to 11.7 inches in diameter, and 13.1 feet in length for diameters beyond that. Ordinary joints are made of lead, special joints by flanges. Leakages seldom occur, and there are no means of preventing their occurrence, but only means of detecting them. The valves are tile valves, and can be moved by means of a screw.

SERVICE PIPES.

The service pipes for distribution of the water for the use of the subscribers are made of drawn iron with screw joints, or more generally of copper with joints of movable flanges. Their diameter varies from .858 to .936 inch. They are placed, like the whole of the pipes in this system, at a depth of 3 feet 11 inches under ground, in order to prevent them from freezing. The copper pipes will last about twenty years, while those made of iron will not last longer than from ten to twelve years on account of their oxidizing more considerably. The pipes for the inlets of motors are of cast iron, and their diameter varies according to the importance of the respective motors; they are in every respect similar to the pipes belonging to the general distribution system.

SECONDARY SERVICE PIPES.

The water for the domestic use of the subscribers is delivered by means of a cock placed on the outside of the walls of the buildings, from which a pipe, generally made of lead, is installed by the subscriber. The service pipes are being maintained at the cost of the subscriber.

QUALITY.

The water from the lake is very pure, the sewers being connected by two large reservoirs, which are emptied into the River Rhone below the works.

The water for domestic use is taken at a depth of 26 feet and at a distance of 1 kilometer (3280 feet) from the port; it is limpid; the temperature varies from 0 to 20 degrees Cent., according to the seasons.

FIRE SUPPLY.

The supply is taken from the general system. Stationary hydrants and movable pumps are being used. There are no pipes fixed into the walls of the houses.

WATER METERS.

The water meters belong to the city and are rented out to the subscribers.

PROJECTED MODIFICATIONS.

Extension of the system for taking the water from the lake to a depth of 78 feet, and later 98 feet, in order to obtain purer water in the summer.

ZURICH, SWITZERLAND.

Zurich, the largest manufacturing town in Switzerland, with its increasing population of about 150,000, is not only the intellectual and commercial capital, but it is the principal seat of the silk industry and the manufacture of machinery. It is the center of nine railways, and its position on the lake of the same name, with its magnificent new quays stretching along each shore for nearly two miles, is unrivalled. The city is divided into two parts by the River Limmat.

In scientific and educational matters the town of Zurich has attained European fame.

It possesses the State Polytechnic Institute, visited from year to year by thousands of young people, both native and foreign.

The waterworks of the city of Zurich are a municipal enterprise.

The total daily consumption ranges from 700,000 to 1,470,000 cubic feet, and is ascertained by measurement of the pumps. About 5125 to 7562 gallons per minute are exclusively used for public fountains.

There are five reservoirs, situated at about 132 to 693 feet above the level of the lowest parts of the city. Their total capacity is 577,500 cubic feet. They are constructed of cemented stone wall.

The water is conveyed by means of eight pumps worked by water-power, steam being only used as a reserve power.

There are two turbines of 100 horse-power each.

The waterworks were installed in the year 1877-78.

There are four pumping mains, 7.8 inches to 17.5 inches in diameter.

The distributing mains cost $965,000 to lay and about $1930 a year to maintain.

The service mains are of cast iron 3.9 to 11.7 inches in diameter.

The service pipes (from service mains to the consumers) are made of

cast iron 1.5 to 3.9 inches in diameter. They are laid and maintained by the municipality at the expense of the consumer.

About 8000 private houses are being served with water.

It is supposed that on an average 145,000 inhabitants draw their supply of water from the municipal waterworks. On the basis of these figures the average consumption is found to be 88.6 gallons per head and day. The maximum consumption for one day was 1,313,900 cubic feet—that is, 132 gallons per head daily.

The increase in the consumption for the year 1897 was 17,789,310 cubic feet, or 5.07 per cent. more than for the year 1896—

	1896 Cubic Feet.	1897 Cubic Feet.	Increase. Percentage.
Water distributed	312,075,400	329,864,910	5.07
Average daily consumption	858,980	903,770	5.07
Maximum consumption (July 6th) .	1,173,000	1,313,900	11.
" " several days,	1,134,000	1,178,590	3.09

The following table shows the various items of the consumption :

		Cubic Feet.
3,093	Subscribers with meter for house, garden and trade . . .	156,541,525
87	Water motors	10,464,770
79	Hydraulic elevators	4,670,015
4,576	Subscribers without meter for house and garden	88,973,955
380	Provisory subscribers for new houses according to estimate	367,500
	Water distributed to the wards Wipkingen and Wollishofen in order to act as a supplement to the spring water, according to estimate	525,000
99	Public buildings, according to meters	13,843,235
	Fountains	2,827,265
	Elevating of the waste water at pump stations on the quays	1,734,180
	Urinals	1,492,050
	Water for fire supply, practice, etc., according to estimate	2,800,000
	For watering of the streets, rinsing out of gutters, according to estimate	10,500,000
	Wells for public use	589,925
	Self-use, cleaning and rinsing out of service pipes, etc. . .	1,400,000
	Losses owing to incorrectness of meters, leaky pipes and breakages in the system	17,500,000
	Total consumption from October 1, 1896, to September 30, 1897	324,438,270

The water having no sediments, there are no arrangements for sedimentation necessary.

Aëration is also unnecessary.

All the water is being filtered, sand filtration being used.

The area of the filters, which are covered, is 24,039 square feet. The water flows into the beds by gravity. Frost and ice have not any influence

Results of Chemical Examinations of the Water.

Before Filtration—Influx into Filters.

1897.	No. of Examin't'ns.	Organic Matter. (Grains to 2.05 Quarts.)			Free Ammonia. (Grains to 2.05 Quarts.)			Albuminoid Ammonia. (Grains to 2.05 Quarts.)			Quality.		
		Max.	Min.	Av.	Max.	Min.	Av.	Max.	Min.	Av.	Max.	Min.	Av.
First Quarter	6	.28	.25	.265	.0015	. . .	.00003	.0009	.0005	.00069	57	40	49
Second Quarter	6	.337	.26	.31	.002	. . .	.0001	.0009	.0006	.00075	72	37	58
Third Quarter	7	.335	.265	.298	.00024	. . .	.00013	.00099	.0005	.00067	76	50	62
Fourth Quarter	7	.352	.28	.315	.00031	. . .	.0002	.001	.00069	.0008	85	56	72
Yearly average	. . .	. . .	. . .	.298	. . .	. . .	.00012	. . .	. . .	.00073	. .	. .	60

After Filtration—Pure Water Reservoir and Network of Pipes.

First Quarter	12	.216	.199	.204	. . .	. . .	. . .	.0003	.00027	.00028	33	27	31
Second Quarter	12	.216	.18	.219	. . .	. . .	. . .	.0003	.00021	.00027	33	30	32
Third Quarter	14	.216	.181	.199	. . .	. . .	. . .	.0003	.00024	.00027	34	30	31
Fourth Quarter	14	.24	.219	.216	. . .	. . .	. . .	.00033	.00027	.00028	37	32	33
Yearly average	. . .	. . .	. . .	.202	. . .	. . .	. . .	. . .	. . .	.00027	. .	. .	32

The Bacteriological Examinations of the Water.

Unfiltered Water—Influx into Filters.

1897.	No. of Examin't'ns.	No. of Bacteria per 35 Cubic Feet.		
		Maximum.	Minimum.	Average.
First Quarter	6	2105	670	1464
Second Quarter . . .	7	580	190	355
Third Quarter . . .	7	742	485	612
Fourth Quarter . . .	8	2645	797	1616
Yearly average .	. .	. .	. .	1011

Filtered Water—Pure Water Reservoir.

First Quarter	25	33	4	18
Second Quarter . . .	26	66	11	23
Third Quarter . . .	27	65	18	33
Fourth Quarter . . .	25	107	6	33
Yearly average .	. .	. .	. .	27

Network of Pipes at Different Stations of High, Low and Medium Pressure.

First Quarter	25	397	25	82
Second Quarter . . .	39	601	19	136
Third Quarter . . .	45	175	27	63
Fourth Quarter . . .	46	423	20	127
Yearly average .	. .	. .	. .	102

whatever on the filters. The sand is very clean and the beds are 3.3 feet in depth. The sand is cleaned by machinery.

Moreover, the water is regularly examined in the chemical laboratories of the municipality.

The fire supply is drawn from the general supply pipes; the number of fire hydrants is about 2000. They are at a distance of about 200 feet from each other.

No more grants are being made for water motors.

The water-power employed in 1897 was as follows:

	Daily Horse-power.
Available water-power	345,155
Created by steam	46,650
Total	391,805

Of this, there was used—

	Daily Horse-power.
For raising water for drinking and for the working of machinery	249,350
For electric lighting and power transmission	105,930
Total	355,280

Unemployed was 9 per cent.; the power employed being therefore 91 per cent.

The inventory of water meters toward the end of the year 1897 showed the following quantities:

Stock on hand from 1896		3468
Purchased in 1897		277
Additional changed apparatus		6
		3751
Deducted: Rejected	4	
Sold	115	119
Total		3632

There are 131 rotation meters installed for motors and elevators. The stock in hand in the workshops is 69, the inventory at the end of the year showing, as reported, 200.

The town of Zurich is perfectly satisfied with its present water system. A project is, however, under consideration for the increase of public fountains supplying spring water.

Typhoid fever cases have decreased relatively at the rate of 75 per cent. since the introduction of this system of purification of the water. The number of cases which arose in 1897 was at the rate of 6.9 per 10,000 inhabitants, the mortality arising from the same source being .88 per 10,000 inhabitants. Since the introduction of filtration these figures have with minor fluctuations been practically the same each year.

Diameters of the Kinds and Sizes of Water Meters in Use.

System.	.35 in.	.46 in.	.7 in.	.99 in.	1.24 in.	1.48 in.	1.93 in.	2.7 in.	3.1 in.	3.9 in.	4.6 in.	5.8 in.	Total.
Dreyer & Rosenkranz	...	...	134	170	76	...	...	8	..	2	1	...	391
Valentin	...	...	66	112	24	...	4	...	...	...	...	...	206
Breslau	...	...	863	535	119	...	17	...	9	...	...	1	1545
Berlin	5	66	377	198	127	1	...	3	...	1	1	...	785
English	...	189	47	116	98	...	8	9	...	7	...	...	473
Spanner	...	...	72	2	...	...	10	...	...	6	...	...	84
Thomson	...	...	105	3	...	...	6	4	...	...	...	1	122
Tylor	...	...	1	...	...	...	...	...	...	3	...	...	1
Meinecke	...	...	1	1	...	...	...	...	...	...	...	...	2
Bopp & Reuther	...	...	10	1	...	...	...	...	...	...	...	...	11
Crown	...	...	1	...	...	...	...	...	...	...	...	...	1
Kennedy	...	...	2	3	...	...	...	1	...	...	...	...	6
Different systems	...	...	3	2	...	...	...	...	...	...	...	...	5
Total	5	255	1682	1143	444	1	45	25	9	19	2	2	3632